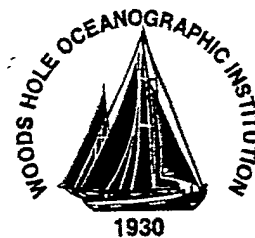


Massachusetts Institute of Technology  
Woods Hole Oceanographic Institution



Joint Program  
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DOCTORAL DISSERTATION

*Baroclinic Vortices Over a Sloping Bottom*

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by

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September 1996

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# BAROCLINIC VORTICES OVER A SLOPING BOTTOM

by

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Submitted in partial fulfillment of the requirements for the degree of  
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## Abstract

Nonlinear quasigeostrophic flows in two layers over a topographic slope are considered. Scaling the lower layer potential vorticity equation yields two parameters which indicate the degree of nonlinearity in the lower layer. The first,  $\frac{U_2}{\beta_2 L^2}$  (the strength of the deep flow divided by the product of the effective bottom slope and the squared length scale), is related to the advection of relative vorticity, and the second,  $\frac{F_2 U_1}{\beta_2}$  (the product of the inverse square deformation radius of the lower layer and the strength of the surface flow divided by the effective slope), to the advection of vorticity due to interfacial stretching.

Two types of isolated vortex are used to examine the parameter dependence. An initially barotropic vortex remains barotropic only when  $\frac{U_2}{\beta_2 L^2} \gg 1$ ; otherwise topographic waves are favored at depth, and the vortex separates into a surface vortex and waves. In the latter case, the surface vortex is weakened, consistent with a simple linear theory. An initially surface-trapped vortex which is larger than deformation scale is baroclinically unstable when  $\frac{F_2 U_1}{\beta_2} > 1$ . If  $\frac{F_2 U_1}{\beta_2} < 1$ , radiation of disturbances hinders or even blocks unstable growth, permitting the existence of large, stable surface vortices.

Both parameters are also relevant to cascading geostrophic turbulence over a slope. If  $\frac{F_2 U_1}{\beta_2} > 1$ , a "barotropic cascade" occurs at the deformation radius (Rhines, 1977) and the cascade is arrested at the scale at which  $\frac{U_2}{\beta_2 L^2} = O(1)$ . The resulting flow is dominated by large scale, anisotropic topographic waves. If  $\frac{F_2 U_1}{\beta_2} < 1$ , layer coupling is hindered and the cascade is arrested at the deformation scale. The flow then is dominated by isotropic surface vortices which continually "leak" energy to topographic waves at a rate proportional to  $\Lambda$ .

In both single vortex and turbulence cases, the distinction between vortices and waves is more transparent when viewing potential vorticity. It is more difficult to identify waves and vortices from the streamfunction fields, because the waves are present in both layers.

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16. Abstract (Limit: 200 words) <p>Nonlinear quasigeostrophic flows in two layers over a topographic slope are considered. The evolution depends on the size of two parameters which indicate the degree of nonlinearity at depth. The first measures the importance of relative vorticity advection and the second of stretching vorticity.</p> <p>Two types of isolated vortex are used to examine the parameter dependence. An initially barotropic vortex remains barotropic only when the first parameter is large, otherwise topographic waves dominate at depth. An initially surface-trapped vortex larger than deformation scale is baroclinically unstable when the second is large, but is stabilized by the slope otherwise.</p> <p>Both parameters are also relevant to cascading geostrophic turbulence. If the stretching parameter is large, a "barotropic cascade" occurs at the deformation radius (Rhines, 1977) and the cascade "arrests" when the relative vorticity parameter is order unity. If small, layer coupling is hindered and the cascade is arrested at the deformation scale, with the flow dominated by isotropic surface vortices.</p> <p>In both cases, the distinction between vortices and waves is transparent when viewing potential vorticity. It is more difficult to identify waves and vortices from the streamfunction fields, because the waves are present in both layers.</p>			
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